IN THE UNITED STATES BANKRUPTCY COURT
FOR THE SOUTHERN DISTRICT OF TEXAS
CORPUS CHRISTI DIVISION

In re:	§	**Case No. 05-21207**
	§	
ASARCO LLC, *et al.*,	§	**Chapter 11**
	§	
Debtors.	§	**Jointly Administered**
	§	

Expert Name: **Shahrokh Rouhani, Ph. D., P.E.**

Retention on behalf of: **ASARCO, LLC**

PROFFER OF DIRECT TESTIMONY OF SHAROKH ROUHANI

Introduction

The following information is a true and accurate statement of my testimony if I were called as a witness in open court in this case.

A. Brief Summary of Opinions

I have been retained by Debtor-in-Possession ASARCO, LLC ("ASARCO") to offer an expert opinion on technical aspects of two documents: (1) a report entitled "Tacoma Smelter Plume Project, Extended Footprint Study," prepared by PGG and TeraStat dated July 2005, (hereinafter referred to as the "Extended Footprint Study" or "the study") and (2) Bruce Peterson's Declaration dated September 19, 2007. The following are the major opinions that I offer in this proceeding:

- The Thiessen analysis presented in the Extended Footprint Study is mathematically flawed.
- The Thiessen analysis presented in the Extended Footprint Study is inconsistent with the standard Thiessen Mapping Method as described in a recent Washington State Department of Ecology ("Ecology") guidance document.
- The presented median and 90th percentile values assigned to polygons in the Extended Footprint Study are statistically unreliable.
- The Extended Footprint Study rejects the appropriate geostatistical methods in favor of a mathematically flawed combination of Thiessen polygons and use of external values.
- The results of the Extended Footprint Study do not provide a basis to make a reliable statistical inference about arsenic concentrations in developed properties.

B. Expert Qualifications

I am an environmental scientist, professional engineer, tenured associate professor at the Georgia Institute of Technology, and the founder/president of NewFields Companies, LLC, a nationwide partnership of environmental experts. I hold a Ph.D. in environmental sciences and an M.S. in environmental engineering, both from Harvard University, as well as a B.S. in civil engineering and a B.A. in economics from the University of California, Berkeley. I have conducted statistical and geostatistical research addressing a variety of sampling and analysis issues, and I have authored and co-authored several publications, including a series of American Society for Testing and Material ("ASTM") standard guides for the application of geostatistics in environmental site investigations, a three-volume guidance document for background data analysis, and an upcoming EPA guidance on soil cleanup strategies at CERCLA sites. I am active in several professional societies and have served on the editorial board of several environmental publications. I was the National Science Foundation visiting scientist at *Centre de Géostatistique, Ecole Nationale Supérieure des Mines de Pairs* in France. My curriculum vitae is attached as Exhibit 165.

C. Statement of Opinions

1. The Extended Footprint Study uses the Thiessen polygon method to map concentrations of arsenic levels measured in soil samples from undeveloped areas. For this purpose, the investigated areas are divided into a number of polygons, where each polygon is associated with a spatial point referred to as a "*location*." According to the authors: "*[t]o best represent the concentration of an analyte at each location the values from all samples at the*

same depth within 300 feet of the location were averaged."[1] The authors then proceed to pool the average values from the nearest ten locations within one mile of the target polygon. These pooled values consist of 1 to 10 values depending on the target polygon.[2] Using the pooled average values, the authors computed median and 90th percentile values and applied them to the target polygon. Subsequent studies prepared for Ecology determined "at risk" polygons as those with assigned 90th percentile arsenic concentrations greater than 100 ppm. This approach contains a number of technical flaws as summarized below.

2. The first major flaw in the Extended Footprint Study Thiessen analysis is that the study authors use average values from outside a polygon's boundary to assign median and 90th percentile values to the polygon itself. On page 11 of the Extended Footprint Study the authors explain, *"[t]herefore, statistics were not calculated from values only within the polygon but from the polygon and the ten nearest neighboring polygons."*[3] As explained in numerous textbooks (e.g., Exhibit 143, Burrough and McDonnell, 1998) and memorialized in various technical guidance documents (e.g., Exhibit 145, Ecology, 2005), the Thiessen mapping technique is specifically designed to represent each polygon by a single value ***internal*** to the actual polygon. As explained in a 2005 Ecology guidance document: "*One procedure to estimate areas associated with each sampling point is the Thiessen Polygon Method. The method assumes that the concentration measured at a given point represents the concentration in the soil out to a distance halfway to all adjacent sampling points. The area associated with each sampling point*

[1] Exhibit 005.0018, Extended Footprint Study, p. 11.

[2] Exhibit 005.0018, Extended Footprint Study, p. 11.

[3] Exhibit 005.0018, Extended Footprint Study, p. 11.

is defined by constructing a Thiessen Polygon network."[4] Pooling values from outside of Thiessen polygons to determine their summary statistics is contrary to the fundamental design of the Thiessen Polygon Method. While pooling of inside and outside values imply strong spatial continuity, Thiessen polygon results in the Extended Footprint Study display abrupt spatial discontinuity along their boundaries. Until this fundamental contradiction is addressed, polygon results presented in the Extended Footprint Study cannot be viewed as mathematically reliable.

3. The second major flaw in the Extended Footprint Study Thiessen analysis is that the study authors computed summary statistics in a manner which renders the resulting statistics unreliable. The study authors computed the summary statistics including the median and 90th percentile values based on only 1 to 10 numbers. This approach would likely yield highly unreliable results. As explained in numerous textbooks and handbooks (e.g., Exhibit 164, NIST Engineering Statistics Handbook, 2006) and memorialized in guidance documents (e.g., Exhibit 144, EPA, 1989), there are specific procedures to quantify the uncertainty associated with an estimated summary statistic.[5] These procedures clearly indicate that attaining acceptable levels of reliability or confidence requires large data sets, especially when the investigated variables display high variations. In fact, the results provided in the Extended Footprint Study indicate that the investigated soil arsenic data-points along the same direction and the same distance from the stack vary by many orders of magnitude. Under such conditions, use of small sets of numbers would yield unreliable summary statistics with large standard errors. Peterson states in his testimony of September 19, 2007 that: "*The color of a polygon indicated the concentration*

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[4] Exhibit 145, Guidance on Remediation of Petroleum-Contaminated Ground Water By Natural Attenuation, Ecology, 2005, p. 96.

[5] *See, e.g.*, Exhibit 144, EPA, 1989, Section 6.3.2, pp. 6-7.

class and the size indicated the uncertainty due to sparse sampling."[6] Relying on the size of each polygon as the measure of uncertainty is an unusual and an inadequate substitute for statistically-based measures of accuracy. Without quantitative measures of accuracy for individual assigned polygon values, such results cannot be viewed as statistically reliable.

4. The third major flaw in the Extended Footprint Study is that the study authors rejected more reliable geostatistical mapping techniques. Ironically, the selection of some of these other more reliable tools would have provided a mechanism to address certain fundamental flaws in the study authors' Thiessen analysis. In contrast to the Thiessen technique, geostatistical techniques permit data from all locations to be used to compute summary statistics of average values over any polygon. For example, the United States Environmental Protection Agency ("EPA") has taken the lead in promoting geostatistics by producing the first public-domain software package, known as Geostatistical Environment Assessment Software ("GEO-EAS").[7] In addition to GEO-EAS, EPA has promulgated another geostatistical package, known as GEOPACK.[8] The successful application of GEO-EAS and GEOPACK prompted the EPA to recommend its use in spatial environmental data analysis in numerous guidance documents, including "Methods for Evaluating the Attainment of Cleanup Standards, Vol. 1: Soils and Solid Media[9] and "Guidance for Data Usability in Risk Assessment."[10]

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[6] Peterson Testimony dated 9/19/07, p.3, paragraph 3.

[7] Englund and Sparks (EPA/600/4-88/033a, 1988). *See* Exhibit 142, GEO-EAS 1.2.1 User's Guide, EPA 4/1991.

[8] Exhibit 141, Yates and Yates (EPA/600/8-90/004, 1990).

[9] Exhibit 144, EPA 230/02-89-042, 1989.

[10] Exhibit 140, EPA/540/R-92/003, 1991.

5. Geostatistical mapping and estimation approaches allow the use of values from outside of a polygon when estimating statistical properties of polygon values. However, values from outside of a polygon are automatically weighted less than the values from inside a polygon depending on their separation distances and spatial correlation. The Extended Footprint Study rejects the use of geostatistical techniques due to some unspecified complexities in the investigated data.[11] Instead, in computing polygon summary statistics, external and internal values are pooled and weighted equally regardless of their separation distances, polygon sizes, or spatial correlations. Such an approach is contrary to geostatistical principles and is in total disregard of fundamental assumptions of the Thiessen technique.

6. In light of the fundamental errors the study authors made in constructing the Thiessen polygons, the polygon "footprint" cannot be viewed as a technically sound conclusion. As discussed above, alternative geostatistical mapping tools were available and rejected by the study authors. The approach proposed by the Extended Footprint Study should be reassessed by either using more appropriate geostatistical tools that properly account for separation distances, polygon sizes, and spatial correlations of sample data beyond polygons or the study should be reassessed by limiting the definition of each Thiessen polygon to the undeveloped sample data within each polygon.

7. My understanding is that Ecology's staff and consultants used the Extended Footprint Study polygons to determine which polygons were "at risk" based on their reported 90th percentile values. Given the unreliability of the reported 90th percentile values, determination of the "at risk" polygons cannot be viewed as a technically sound conclusion.

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[11] Exhibit 005.017, Extended Footprint Study, p. 10.

8. The Extended Footprint Study categorically excludes all soil sample data from developed properties. Peterson's testimony of September 19, 2007 clearly indicates that soil arsenic concentrations in undeveloped areas are statistically different from those measured in developed areas.[12] In absence of a technically sound correlation analysis between undeveloped and developed datasets, no reliable statistical inference can be made about arsenic concentrations in developed properties based on the results of Extended Footprint Study.

9. Although no reliable statistical inference can be drawn on developed properties within at-risk properties, Ecology's staff and consultants rely on the Extended Footprint Study to draw inferences regarding such developed properties. In my opinion, the Extended Footprint Study is not a valid basis for establishing undeveloped property counts because its analyses categorically exclude data from developed areas.

D. Exhibits to be Introduced in Support of Direct Testimony

- Exhibit 143: Burrough, P.A., and R. A. McDonnell, "Principles of Geographical Information Systems," Oxford University Press, 1998.
- Exhibit 142: Englund, E., and A. Sparks, GEO-EAS (Geostatistical Environmental Assessment Software) User's Guide, EPA600/4-88/033, ENMSL, Environmental Protection Agency, Las Vegas, 1988.
- Exhibit 164: NIST Engineering Statistics Handbook, NIST/SEMATECH e-Handbook of Statistical Methods, http://www.itl.nist.gov/div898/handbook/, last updated 2006.
- Exhibit 144: United States Environmental Protection Agency (EPA), Methods for Evaluating the Attainment of Cleanup Standards, Volume 1: Soils and Solid Media, EPA230/02-89-042, 1989.
- Exhibit 141: United States Environmental Protection Agency (EPA), Geostatistics For Waste Management: User's Manual For the GEOPACK (Version 1.0), developed by S.R. Yates and M.V. Yates, EPA/600/8-90/004, 1990.

[12] Peterson's Testimony dated 9/19/07, p. 6, paragraph 16.

- Exhibit 140: United States Environmental Protection Agency (EPA), Guidance for Data Usability in Risk Assessment, EPA/540/R-92/003, 1991.

- Exhibit 145: Washington State Department of Ecology, Guidance on Remediation of Petroleum-Contaminated Ground Water By Natural Attenuation, July 2005.

Pursuant to 28 U.S.C. § 1746, I declare under penalty of perjury that the foregoing is true and correct. Executed this 23rd day of September 2007 in Atlanta, Georgia.

S. Rouhani

Shahrokh Rouhani, Ph.D., P.E.

NEWFIELDS

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EDUCATIONAL BACKGROUND

Ph.D.	1983	Harvard University	Environmental Sciences
S.M.	1980	Harvard University	Engineering
B.A.	1978	University of California, Berkeley	Economics
B.S.	1978	University of California, Berkeley	Civil Engineering

PROFESSIONAL EXPERIENCE

President	NewFields, Inc.	1995 - Present
President	NewFields Companies, LLC	2002 - Present
Adjunct Professor	School of Civil and Environmental Engineering Georgia Institute of Technology	1996 - Present
Editorial Board Member	*Environmental Forensics* Association for Environmental Health and Sciences	2003 - Present
Associate Professor	School of Civil and Environmental Engineering Georgia Institute of Technology	1990 - 1996
Senior Consultant	Dames & Moore Atlanta, GA	1990 - 1995
Chairman	National Ground Water Hydrology Committee, Hydraulics Division, American Society of Civil Engineers	1991 - 1992
Expert Member	ASTM/EPA/USGS/DOD Geostatistics Standardization Committee	1991 - Present
Associate Editor	*Water Resources Research* American Geophysical Union	1989 - 1994
Assistant Professor	School of Civil Engineering Georgia Institute of Technology	1983 - 1990

Chairman	Task Committee on Geostatistical Techniques in Geohydrology, American Society of Civil Engineers	1987 - 1989
National Science Foundation Visiting Scientist	Centre de Géostatistique, Ecole Nationale Supérieure des Mines de Paris, France	1987 - 1988

PROFESSIONAL REGISTRATION

Licensed Professional Engineer Georgia (Registration Number 19369)

CURRENT FIELD OF INTEREST

Geostatistics
Decision Analysis
Environmental Statistics
Geostatistical and Stochastic Hydrology
Surface and Groundwater Hydrology

HONORS AND AWARDS

Tau Beta Pi (National Engineering Honor Society)	1977
Chi Epsilon (Civil Engineering Honor Society)	1978
Phi Beta Kappa (National Honor Society for Students in Social Sciences)	1978
Watson Award, Division of Applied Sciences, Harvard University	1979-82
Sigma Chi (Scientific Research Society)	1987
1990 Who's Who (Rising Young Americans)	1990
ASCE Task Committee Excellence Award, Hydraulics Division (S. Rouhani, Chairman of ASCE Task Committee on Geostatistical Techniques in Geohydrology)	1991
Dictionary of International Biography - 22nd Edition	1992
Two Thousand Notable American Men, First Edition	1992
Who's Who in America	1995-Present

NEWFIELDS REPRESENTATIVE PROJECT EXPERIENCE

Statistical Source Contamination Identification, Coleman-Evans Superfund Site, Whitehouse, Florida – On behalf of EPA, extensive historical soil data were analyzed in order to determine the extent of ambient versus site-related dioxins.

Geostatistical Source Impact Delineation, Mission Valley, San Diego, California – Extensive BTEX, MTBE groundwater database was geostatistically analyzed in order to define the extent of site-related plumes.

Anniston Lead Site – Lead negotiation, cleanup, and sampling efforts at Anniston Lead Site. These efforts included statistical and geostatistical analyses of soil lead and PCB data in order to verify the extents of zones of investigations.

Groundwater Chlorinated Solvent Contamination Class Certification Evaluation - Extensive

historical groundwater data from a region in Ohio were compiled and analyzed in order to evaluate the proposed class certification in a federal case of chlorinated solvent contamination in a mixed urban/rural area. For this purpose, multivariate statistical and geostatistical techniques were employed, which clearly indicated the presence of multiple sources unrelated to the defendants' activities.

Groundwater MTBE Contamination Class Certification Evaluation – Available historical groundwater MTBE data from a region in Connecticut were compiled and analyzed in order to evaluate the proposed class certification in a state case of chlorinated solvent contamination in a suburban area. For this purpose, multivariate statistical and geostatistical techniques were employed, which clearly indicated the limited extent of contamination associated with the defendant's facility.

United Nations Compensation Commission Expert Assessment **–** Extensive sediment and soil data provided associated with the environmental damages from post-1991 Kuwait conflict were statistically and geostatistically analyzed. These analyses were conducted as part of the UNCC technical review of submitted claims.

St. Johns River Water Management District Minimum Flow Determination – Developed an innovative combined hydrodynamic and statistical approach to establish minimum flow levels for Blue Spring based on protection of manatees winter refuge criteria.

St. Johns River Water Management District Geostatistical Peer Review – Lead technical reviewer for numerous projects at SJRWMD, including optimization of groundwater monitoring networks, mapping of potentiometric surfaces, groundwater flow modeling, assessment of seagrass monitoring protocols, Lake Apopka soil data analysis, and time series analysis of groundwater and lake monitoring data.

South Florida Water Management District Lower West Coast Potentiometric Mapping – Technical lead on statistical and geostatistical analysis of available seasonal, multi-layer groundwater elevation data for Lower West Coast potentiometric Mapping.

US Navy CURT (Clean Up Review Team). - Technical lead on strategic review of US Naval environmental projects worldwide. In this role Dr. Rouhani has assisted US Navy to review more than 750 projects and identify more than $100 million in cost-avoidance.

US EPA Project on Multivariate Geostatistical Trend Detection and Network Design for Acid Deposition Data. Principal investigator for development of a multivariate geostatistical technique for trend detection in acid deposition data and spatial evaluation of current national network, known as NAPD/NTN.

US Department of Energy Project on Application of Geostatistical Methods to Savannah River Site Environmental and Geotechnical Investigation - Principal investigator for development and application of advanced procedures for evaluation of the adequacy of groundwater quality data at a waste site, as well as development of geostatistical estimation/simulation procedure in support of seismic modeling of the site.

Mole Pier, San Diego Naval Station - Projector Director for the data evaluation and analysis of the anticipated $40 million dollar clean up project.

Allen Harbor Landfill, North Kingstown, RI - Projector Director for updating superfund remedy selection. The original cap remedy was cost estimated at $14 million.

Spatial Statistical Assessment. Performed an extensive soil and groundwater analysis at a CERCLA site in Baton Rouge, Louisiana. Site was geostatistically analyzed in order to perform four major tasks: (1) to characterize three-dimensional soil contamination mapping, (2) to calculate block-area groundwater contamination levels, (3) to produce sampling plans for subsequent measurements, and (4) to provide most accurate information on the spatial distribution of parameters of the groundwater flow/transport model of the site.

Groundwater statistical optimization. Assessement of soil and groundwater at manufacturing facility in Athens, Georgia. Geostatistics was used to (1) characterize the groundwater contamination in a three-dimensional framework, and (2) identify areas which exhibit either data gaps, or potentially elevated contaminations. Geostatistically produced kriged and quantile maps were used to characterize the site contamination, as well as identify location for subsequent sampling activities.

Statistical risk evaluation. Principal investigator for risk assessment study of a major development site in Detroit Michigan. Geostatistics was used to estimate surface soil block contamination, evaluate the adequacy of the existing surficial measurements, and design an information-efficient deep soil sampling plan.

Soil characterization planning and optimization. An innovative phased geostatistical sampling plan was developed to characterize soil and groundwater contamination at a RCRA industrial site in South Carolina.

Groundwater transport modeling for remedial evaluation. Determined the effectiveness of a proposed list of groundwater remedial alternatives at a CERCLA site through the use of U.S. Geological Survey groundwater flow/transport model, MOC-2D. The results of model provided a realistic assessment of long-term potential efficiency of the various pump-and-treat alternatives.

Risk evaluation of contaminated soils. Existing soil data from an abandoned industrial site in Michigan were geostatistically analyzed to perform two tasks: (1) to characterize the site contamination in a multi-layer framework, and (2) identify areas which exhibit either data gaps, or potentially elevated contaminations.

Phased sampling planning. Existing soil data from an industrial landfill in West Pittsburg, California were analyzed in order to produce an elaborate phased sampling plan. The plan included a series of interconnected rule-based stages that allow the decision-maker to pursue the sampling activity in an efficient manner, using a variety of geostatistical, statistical, and deterministic techniques.

Statistical assessment of migration potential. For a project in Memphis, Tennessee, existing data on the thickness of a critical near-surface aquitard were geostatistically analyzed in order to determine zones of potential leakage to the lower aquifer.

GEORGIA TECH REPRESENTATIVE RESEARCH EXPERIENCE

Title:	Optimal Sampling of Stochastic Processes
Sponsor:	National Science Foundation
Duration:	(6/1/85 to 10/30/87)
Subject:	In this project, Dr. Rouhani developed optimal sampling and monitoring techniques for ground water quantity and quality investigations, based on advanced geostatistical procedures. It was shown that using such techniques can yield economically efficient sampling plans.
Title:	Optimal Schemes for Ground Water Quality Monitoring in the Shallow Aquifer, Dougherty

	Plain, Southwestern Georgia
Sponsor:	U.S. Geological Survey
Duration:	(4/1/86 to 3/31/87)
Subject:	In this project, Dr. Rouhani developed a flexible geostatistical procedure for planning a ground water quality monitroing network in Dougherty Plain, Georgia. The proposed network acts as a warning system for the protection of the Floridan Aquifer system which is a major source of water in south Georgia and Florida.
Title:	Advanced Geostatistical Studies at the Centre de Geostatistique, Ecole des Mines de Paris.
Sponsor:	National Science Foundation
Duration:	(9/1/87 - 2/18/89).
Subject:	Through this project Dr. Rouhani developed new techniques for statistical analysis of space-time data, including air pollution and ground water contamination data. The budget of this project was the highest amount awarded by the NSF's "U.S. - Industrialized Countries Program for the Exchange of Scientists and Engineers" in 1987.
Title:	Geostatistical Evaluation of Flow Parameters
Sponsor:	U.S. Geological Survey
Duration:	(4/1/90 - 3/31/91)
Subject:	Dr. Rouhani developed techniques for efficient estimation of ground water flow parameters based on available hydrogeological field data.
Title:	Multivariate Geostatistical Trend Detection and Network Design for Acid Deposition Data
Sponsor:	U.S. Environmental Protection Agency
Duration:	(3/1/1991 -9/30/1991)
Subject:	Dr. Rouhani developed a multivariate geostatistical technique for trend detection in acid deposition data and spatial evaluation of current national network, known as NAPD/NTN.
Title:	Multilayer Geostatistical Ground Water Flow and Transport Modeling
Sponsor:	HazLab, Inc.
Duration:	(6/20/92 -12/30/92)
Subject:	Dr. Rouhani developed a combined deterministic/geostatistical groundwater flow/transport model.
Title:	Velocity/Lithology Model Database, Statistical Models of Soil Columns Velocity, and Maps of Model Layers
Sponsor:	Westinghouse Savannah River Company / U.S. DOE
Duration:	(1/1/1993-6/30/1993)
Subject:	Dr. Rouhani developed a relational database and conducted extensive geostatistical analyses of seismic data.
Title:	Application of Geostatistical Methods to SRS Groundwater Monitoring and Environmental Risk
Sponsor:	Westinghouse Savannah River Company / U.S. DOE
Duration:	(7/1/1993-10/15/1993)
Subject:	Dr. Rouhani developed procedures for evaluation of the adequacy of groundwater quality data at a waste site.
Title:	H-Area/ITP Geostatistical Assessment of In-situ and Engineering Properties
Sponsor:	Westinghouse Savannah River Company / U.S. DOE
Duration:	(1/1/1994-6/30/1995)

Subject: Dr. Rouhani will develop geostatistical estimation/simulation procedure in support of seismic modeling of the site.

PUBLICATIONS

Published Books and Parts of Books

1. Rouhani, S., and T.J. Hall, "Geostatistical Schemes for Groundwater Quality Management in Southwest Georgia," in *Pollution, Risk Assessment, and Remediation in Groundwater Systems*, pp. 197-223, R.M. Khanbilvardi and J. Fillos, Eds., Scientific Publications Co., Washington, DC, 1987.
2. Rouhani, S., and R. Kangari, "Landfill Site Selection," in *Expert Systems: Applications to Urban Planning*, Ch. 10, T.J. Kim *et al.*, Eds., Springer-Verlag, 1989.
3. Lennon, G.P., and S. Rouhani, Eds., *Ground Water*, Proceedings of the ASCE International Symposium on Ground Water, ASCE, 1991.
4. Rouhani, S., R. Srivastava, A. Debarats, M. Cromer, and I. Johnson, Eds., "*Geostatistics for Environmental and Geotechnical Applications*," STP 12 83, ASTM, 1996.

Standards and Guidance Documents (Main Author/Contributing Author)

1. American Society of Testing and Materials (ASTM), *Standard Guide for Reporting Geostatistical Site Investigations*, D5549-94, 1994.
2. American Society of Testing and Materials (ASTM), *Standard Guide for Analysis of Spatial Variation in Geostatistical Site Investigations*, D5922-96, 1996.
3. American Society of Testing and Materials (ASTM), *Standard Guide for Selection of Kriging Methods in Geostatistical Site Investigations*, D5923-96, 1996.
4. American Society of Testing and Materials (ASTM), *Standard Guide for Selection of Simulation Approaches in Geostatistical Site Investigations*, D5924-96, 1994.
5. Department of Navy (DON), *Guidance for Environmental Background Analysis, Volume I: Soil*, NFESC User's Guide, UG-2049-ENV, April 2002.
6. Department of Navy (DON), *Guidance for Environmental Background Analysis, Volume II: Sediment*, NFESC User's Guide, UG-2054-ENV, April, 2003.
7. Department of Navy (DON), *Guidance for Environmental Background Analysis, Volume III: Groundwater*, Final, April, 2004.
8. United States Environmental Protection Agency (US EPA), *Guidance for Soil Cleanup Strategies*, Draft, 2003.

Published Journal Papers (refereed)

1. Rouhani, S., "Variance Reduction Analysis", *Water Resources Research*, Vol. 21, No. 6, pp. 837-846, June, 1985.
2. Rouhani, S., "Comparative Study of Ground Water Mapping Techniques", *Journal of Ground Water*, Vol. 24, No. 2, pp. 207-216, March-April 1986.
3. Rouhani, S., and Fiering, M.B., "Resilience of a Statistical Sampling Scheme," *Journal of Hydrology*, Vol. 89, No. 1, pp. 1-11, December, 1986.
4. Rouhani, S., and Kangari, R., "Landfill Site Selection: A Microcomputer Expert System," *International Journal of Microcomputers in Civil Engineering*, Vol. 2, No. 1, pp. 29-35, March, 1987.
5. Rouhani, S., and Hall, T.J., "Geostatistical Schemes for Groundwater Sampling," *Journal of Hydrology*, Vol. 103, 85-102, 1988.
6. Rouhani, S., and Cargile, K.A., "A Geostatistical Tool for Drought Management," *Journal of Hydrology*, Vol. 106, 257-266, 1989.
7. ASCE Task Committee on Geostatistical Techniques in Geohydrology (S. Rouhani, Chairman and Principal Author), "Review of Geostatistics in Geohydrology, 1. Basic Concepts," *ASCE Journal of Hydraulic Engineering*, 116(5), 612-632, 1990.

8. ASCE Task Committee on Geostatistical Techniques in Geohydrology (S. Rouhani, Chairman and Principal Author), "Review of Geostatistics in Geohydrology, 2. Applications," *ASCE Journal of Hydraulic Engineering*, 116(5), 633-658, 1990.
9. Rouhani, S., and H. Wackernagel, "Multivariate Geostatistical Approach to Space-Time Data Analysis," *Water Resources Research*, 26(4), 585-591, 1990.
10. Rouhani, S. and D.E. Myers, "Problems in Space-Time Kriging of Geohydrological Data," *Mathematical Geology*, 22(5), 611-624, 1990.
11. Loaiciga, H.A., R.J. Charbeneau, L.G. Everett, G.E. Fogg, B.F. Hobbs, and S. Rouhani, "Review of Ground-Water Quality Monitoring Network Design," *ASCE Journal of Hydraulic Engineering*, 118(1), 11-37, 1992.
12. Rouhani, S., R. Ebrahimpour, I. Yaqub, and E. Gianella, "Multivariate Geostatistical Trend Detection and Network Evaluation of Space-Time Acid Deposition Data, 1. Methodology," *Atmospheric Environment*, 26A(14), 2603-2614, 1992.
13. Rouhani, S., R. Ebrahimpour, I. Yaqub, and E. Gianella, "Multivariate Geostatistical Trend Detection and Network Evaluation of Space-Time Acid Deposition Data, 2. Application to NADP/NTN Data," *Atmospheric Environment*, 26A(14), 2615-2626, 1992.
14. Casado, L., S. Rouhani, C. Cardelino, and A. Ferrier, "Geostatistical Analysis and Visualization of Hourly Ozone Data," *Atmospheric Environment*, 28(12), 2105-2118, 1994.
15. Rouhani, S., Geostatistical Estimation: Kriging, in Rouhani et al., Eds., "*Geostatistics for Environmental and Geotechnical Applications*," STP 12 83, ASTM, 1996.
16. Wild, M. R., and S. Rouhani, Effective Use of Field Screening Techniques in Environmental Investigations: A Multivariate Geostatistical Approach, in in Rouhani et al., Eds., "*Geostatistics for Environmental and Geotechnical Applications*," STP 12 83, ASTM, 1996.
17. Lin, Y. P., and S. Rouhani, "Geostatistical Analyses for Shear Wave Velocity," *J. of The Geological Society of China*, Vol. 40, No. 1, p 209-223, 1997.
18. Lin, Y.P., and S. Rouhani, "Multiple-Point Variance Analysis for Optimal Adjustment of A Monitoring Network," *Environmental Monitoring and Assessment*, 69(3), pp. 239-266, 2001.
19. Lin, Y. P., Y. C. Tan, and S. Rouhani, "Identifying Spatial Characteristics of Transmissivity Using Simulated Annealing and Kriging Methods," *Environmental Geology*, 41:200-208, 2001

Published Research Reports

1. Rouhani, S., "Toward a More Efficient Farm Level Models," presented at the seminar on water management planning in Pakistan, Development Research Center, World Bank, Washington, DC, *Ford-Pakistan Project Annual Progress Report*, 1980.
2. Chaudri, A., S. Rouhani and P.P. Rogers, "Hydrology of Induced Recharge in Indus Basin Pakistan," Department of City and Regional Planning, Harvard University, 1980.
3. Rouhani, S., "Toward a More Effective Indus Basin Model, Waterlogging and Salinity Considerations," presented at the Tri-partite meeting in Pakistan, Development Research Center, world Bank, Washington, DC, *Ford-Pakistan Project Annual Progress Report*, 1981.
4. Rouhani, S. and T. J. Hall, "Optimal Schemes for Ground Water Quality Monitoring in the Shallow Aquifer, Dougherty Plain, Southwestern Georgia," Technical Completion Report, U.S. Dept. of Interior/USGS Project G-1219(05), ERC 05-87, Environmental Resources Center, Georgia Institute of Technology, Atlanta, Georgia, 49 p., 1987.
5. Rouhani, S., "Optimal Sampling of Stochastic Processes," Final Technical Research Report, National Science Foundation, Grant No. ECE-8503897, School of Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia, p. 170,1987.
6. Rouhani, S., "L'Analyse de Donnees Geohydrologiques," *De Geostatisticis*, No. 3, pp. 5-6, August, 1988.
7. Rouhani, S., "Advanced Geostatistical Studies at the Centre de Geostatistique, Ecole des Mines de Paris," Final Technical Research Report, National Science Foundation, Grant No. INT-8702264,

School of Civil Engineering, Georgia Institute of Technology, Atlanta, GA, 129 p., May 1989.

8. Rouhani, S., "Geostatistics: Theory, Practice, and Personal Computer Applications," Education Extension, Georgia Institute of Technology, September, 1989.
9. Rouhani, S., R. Ebrahimpour, I. Yaqub, and E. Gianella, "Multivariate Geostatistical Trend Detection and Network Evaluation of Space-Time Acid Deposition Data," Final Technical Report, AREAL, U.S. Environmental Protection Agency, Contract 68-D0-0095, RTP, NC, 320 p., October, 1991.
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4. Rouhani, S., and R. Kangari, "Expert Systems in Water Resources," *Water for the Future: Hydrology in Perspective*, J. C. Rodda and N.C. Matalas, Eds., pp. 457-462, International Association of Hydrological Sciences, Publication No. 164, 1987.
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PROFESSIONAL ACTIVITIES

1. American Geophysical Union:
   Member, 1981-Present.
   Associate Editor, *Water Resources Research*, 1989-1994.
2. American Society of Civil Engineering:
   Associate Member, 1983-1987.
   Member, 1987-Present.
   Chairman, National Ground Water Hydrology Committee (Standing Committee), Hydraulics Division, Oct. 1991-1992.
   Chairman, ASCE Task Committee on Geostatistical Techniques in Geohydrology, Ground Water Hydrology Technical Committee, American Society of Civil Engineers, Hydraulics Division, Oct. 1987-Sept. 1989.
   Contact Member, ASCE Task Committee on Groundwater Monitoring Network Design, Probabilistic Approaches to Hydraulics and Hydrology Committee, Hydraulic Division, Oct. 1988- Sept. 1990.

Secretary, ASCE Water Resources Committee, American Society of Civil Engineers, Georgia Section, 1988.

Special Session Organizer,
Special Session on "Development and Applications of Geostatistics in Geohydrology," 1989 ASCE National Conference on Hydraulic Engineering, New Orleans, August 14-18, 1989.

Special Session Organizer and Chairman,
Special Session on Geostatistics in Geohydrology, 1990 ASCE Water Resources Conference, Fort Worth, April, 1990.

Symposium Organizer,
International Symposium on Ground Water, 1991 ASCE National Conference on Hydraulic Engineering, Nashville, July, 1991.

3. International Water Resources Association: Member, 1985-Present.
4. American Water Resources Association: Member, 1986-Present.
5. North American Council on Geostatistics, 1987-Present.
6. International Geostatistical Association: Member, 1989-Present.
7. Association for Environmental Health and Sciences (AEHS): Member, 2003-Present.
   Member of Editorial Board, *Environmental Forensics*, 2003-Present.